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ELECTROSTATIC PRECIPITATORS FOR DUST REMOVAL FROM CEMENT GRINDING MILLS

[Elektrofilter für die Entstaubung von Zementmühlen]

K. Arras

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(22)

ELECTROSTATIC PRECIPITATORS FOR DUST REMOVAL FROM CEMENT GRINDING MILLS

K. Arras

1. Introduction

Modern cement plants use electrostatic precipitators almost exclusively for dust removal from rotary cement kilns and drying facilities for ground raw material. In contrast, in the case of purification of the spent air from cement grinding mills, it is a question of the most suitable dust removal procedure. The operator must then decide between fiber filters and electrostatic precipitators.

Consequently, below we report on experiences with electrostatic precipitators in the removal of dust from the spent air of cement grinding mills. We expect an increase in the interest towards the use of electrostatic precipitators, in keeping with the increase in the capacity of these mills anticipated for the future.

As is known, the spent air of the mill must be conditioned by water injection to achieve unobjectionable operation of electrostatic precipitators. Some of the cement experts see a danger of reduced quality in the cement, if the amount of water exceeds 1% of the

mill's capacity. This has been predominantly true in the case of the facilities described below.

Other operators fear operational difficulties during start-up and shut-down operations, which often must be performed without water injection.

However, the most recent studies have shown that with proper dimensioning of the electrostatic precipitator and the use of special electrodes, the amount of water to be injected during continuous operation can be reduced significantly. Furthermore, the start-up and shut-down operations can be performed without water injection. This was confirmed during operations with a full-scale facility.

The general validity of these results can, however, not yet be assumed with adequate certainty. However, we can rely on the fact that in the future it will be possible to operate electrostatic precipitators in cement grinding mills with much smaller amounts of water injected into the process.

2. Principles of construction of electrostatic precipitators

The first electrostatic precipitators for the purification of the spent air of a cement grinding mill were installed over 30 years ago. Due to the reduced mill capacity, large specific spent air throughputs were possible, keeping the temperatures in the electrostatic precipitator sufficiently low. It was therefore possible to build a stable electric field without additional moisture. Since, furthermore, the requirements of dust content in the spent air were comparatively low, even for cement grinding mills, the facility worked to the operator's satisfaction.

Routine measurements at a vertical filtering facility installed

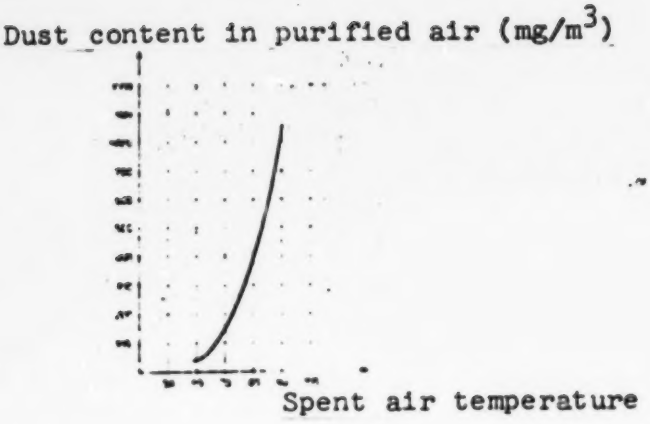

Figure 1. Dust content in purified air as a function of temperature

over 20 years ago showed a dust content in the purified spent air of between 50 and 150 mg/m^3, at spent air temperatures of near 60 to 70°C, for the grinding of normal cement. However, these values increased by a factor of up to 10 for the grinding of high-grade cements, in which case the temperatures increased to 90 to 100°C. Figure 1 clearly shows the dust content in purified air as a function of spent air temperatures.

As in all industrial fields, today the construction of the more expensive vertical filters has been abandoned also by the cement industry, in favor of the use of horizontal filters. Normally, filters with one or two electric fields are used, coupled - depending on the dust load - to a preliminary separator installed in the crude gas feed pipe. Because of the continuously increasing mill capacities and the correspondingly increased amounts of spent air, today's cement grinding mills are already using electrostatic precipitators with field heights of 9 m.

Experience has shown that even single field facilities can

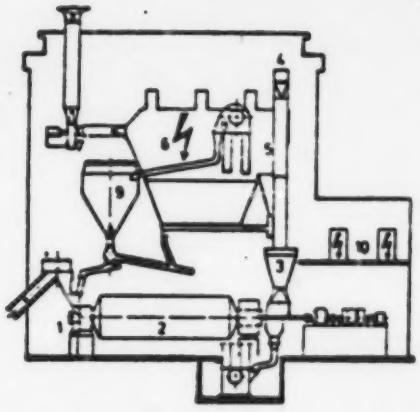

Figure 2. Schematic for a modern cement plant.

1 Air supply feed pipe	6 Electrostatic precipitator
2 Tube mill	7 Blower
3 Gravel separator	8 Cyclic bucket conveyor
4 Diffusor	9 Sifter
5 Louver-type preliminary separator	10 High voltage generator

easily meet official requirements with respect to the dust content in purified air, if the proper dimensioning is used. It is quite unimportant, in this case; whether the cement grinding mill's spent air has part of the dust removed by a cyclone prior to the precipitator, or not.

Figure 2 shows a modern cement grinding facility. Its simple construction is appealing: tube mill, gravel separator, electrostatic precipitator, spent air blower. This makes favorable channeling possible. In addition, all of the dust collected by the electrostatic precipitator can be added to the final product.

Figure 3 shows the construction principles of a horizontal filter including louver-type preliminary separator (a two-field version is shown).

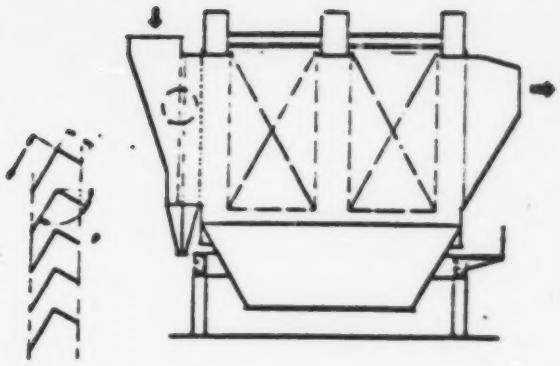

Figure 3. Horizontal electrostatic precipitator with preliminary separator.

The louver-type preliminary separator makes it possible to eliminate 65 to 80% of the dust fed to the electrostatic precipitator. The pressure drop involved is of the order of magnitude of 25 mm water column. Extensive investigations have shown that the louver-type separator has the advantage over a cyclone of not operating selectively. This results in an even separation of practically all the fractions. Hence, all the dust separated in the electrostatic precipitator, from the preliminary separator to the electrostatic precipitator itself, can be added to the finished product. The assumption that a gravel separator - which retains excessively large particles - precedes the electrostatic precipitator system is implicit.

Let us give a few figures to illustrate the effect of the preliminary separator. They were obtained from an electrostatic precipitator facility used in the dust removal from a cement grinding mill with an output of 75 t/h, for the grinding of normal cement. For a crude gas content of 325 g/Bm^3, the degree of separation of the preliminary separator was 65%, i.e., 210 g/Bm^3 of dust were collected under the preliminary separator. Hence, approximately 115 g/Bm^3 -

TABLE 1. PARTICLE SIZE ANALYSIS ON CEMENT GRINDING MILL DUST

	Particle size in µm								Amount of product, in %
	0 - 5	5 - 10	10 - 20	20 - 30	30 - 40	40 - 60	60 - 80	- ∞	
Dust from gravel separator	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Gravel from sifter	-	-	-	-	-	[illegible]	[illegible]	[illegible]	
Finished product from sifter	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Dust from electrostatic precipitator deposit under the preliminary separator	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	[illegible]
Dust from the electrostatic precipitator under the electric fields	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total finished product	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Smaller than 60 µm
All data in %

corresponding to 35% of the total dust content - remained for the electrostatic precipitator. The particle size analyses, compiled in Table 1 for the whole mill system, show that for particles of 5 µm or larger there is no significant practical difference between the dust separated by the preliminary separator and by the electric field.

Normally, the deposit placed under the electrostatic precipitator has the form of a trough. A conveyor belt is placed below the precipitator trough, which transports all of the dust collected by the electrostatic precipitator to a bucket wheel sluice. It leads to an air conveyor slot for the removal of the material. The dust from the preliminary separator can be added to the conveyor beyond the dust sluice. In this manner, if the direction of motion of the conveyor is opposite to that of the gas flow, then the conveyor will not be loaded with the total weight of dust. It is, of course, also possible to place a pointed bin under each force field from which the dust separated can be fed directly to the air conveyor slot by means of an air-tight sealing mechanism.

Figure 4 shows the space saving construction of the louver-type

Figure 4. Preliminary separator in a cement grinding mill filter.

preliminary separator.

3. Effect of the spent air humidity on the degree of separation

In practice, the humidity content of the spent air of a cement grinding mill corresponds to the atmospheric moisture content. However, if an unobjectionable operation of the electrostatic precipitator is to be achieved, certain requirements are imposed on the conditions of the gas or air used, especially with respect to moisture content. Figure 5 represents the filtering effect as a function of gas temperature and dew point, as obtained in an operating facility. One can see that current requirements decrease as the temperature is increased and as the dust content of the purified gas increases.

If, at higher spent air temperatures, the dew point also decreases, then the current consumption is reduced to almost zero, and the dust content in the purified air jumps to almost 10-fold that of normal operating conditions. An area of increased dust resistance is reached,

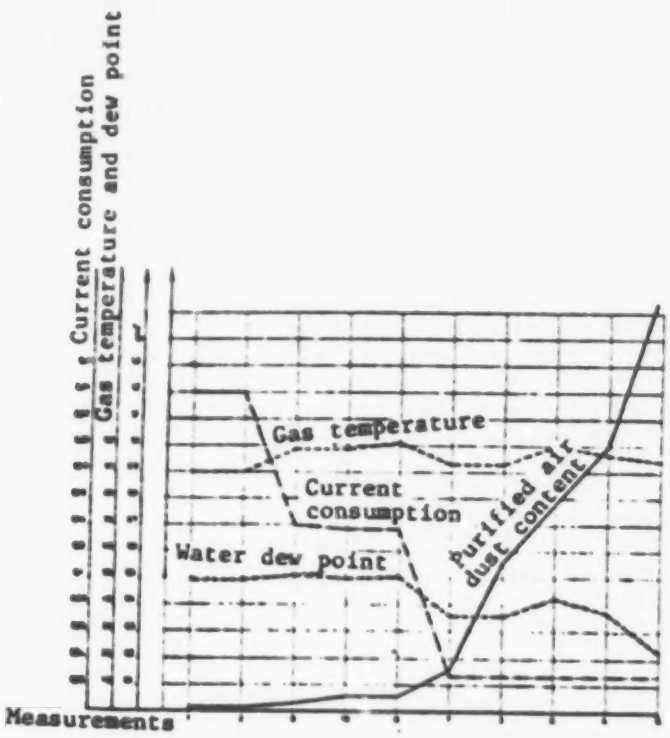

Figure 5. Current consumption and dust content in the purified air as a function of the gas temperature and dew point.

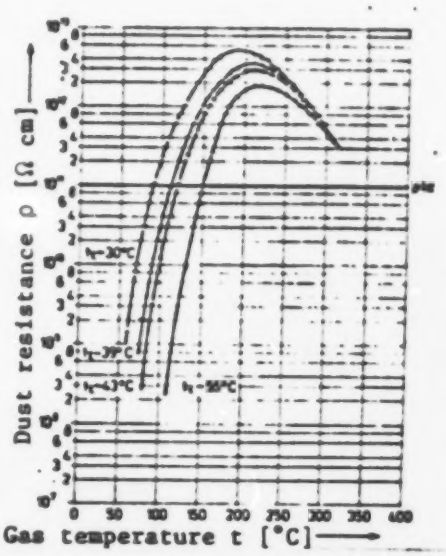

Figure 6. Electric resistance of dust in the spent air of a cement grinding mill.

the dust removal problems of which are already known from heat exchange furnaces.

Dust resistance measurements performed on the spent air of a cement grinding mill showed, in fact, the well known relationships (Figure 6).

Dust resistance values are plotted as a function of the temperature, with the dew point as the parameter. Depending on the water dew point, the curves intersect the critical limit at temperatures between 90° and 150°C. They are only valid, however, for the particular cement grinding facility where the measurements were taken.

The intersection point between the individual curves and the so-called critical dust resistance value can be significantly displaced from one installation to another, a fact that must be taken into consideration in the design of electrostatic precipitator facilities.

As the measurements show, it is necessary to raise the dew point at higher air temperatures to achieve unobjectionable operation of the electrostatic precipitator. The problem is similar to that of the purification of the spent air from hot rotary kilns, with the significant difference that here water has to be vaporized at especially low temperatures. This eliminates spent air conditioning in the evaporation cooler, or water injection into the feed channels of the electrostatic precipitator, due to the danger of deposit formation. The only possibility that remains is injection of water directly into the rotating mill, since here the temperatures are highest because of the size reduction process. Furthermore, the continuous movement of the grinder works against any possible deposit formation.

As experience has shown, an injection of water in amounts of 2 or 3% of the grinding capacity can reduce the spent air volume of the cement grinding mill by about 50%. Of course, this works in favor of

the entire dust removal installation, since it makes smaller dimensions possible for the filter. Furthermore, energy consumption values are favorably affected due to the reduction in the air volume required. In addition, the reduction in air volume results in advantages in the construction of the mill, in that it permits the use of smaller collar bearings in some circumstances.

It is known that the grinding capacity of a mill is reduced when the operating conditions are such that there are high air temperatures at low moisture content. This is due to the reduction in the dust conductivity: the dust can not discharge the friction-generated electrical charges it carries. The dust becomes attached to the grinding balls and the walls of the mill, and the grinding elements' action is damped. This coating of the grinding balls with high resistance dust can reduce the grinding capacity of the mill considerably. This disadvantageous effect can be eliminated - or at least, considerably reduced - by water injection.

4. Water injection in a cement grinding mill.

Inappropriate water injection can lead to problems in the form of deposit formation and clogging in a cement grinding mill.

Figure 7 shows a louvered slide in a two-chamber mill, clogged by water injection. Clogging can be caused both by inadequate positioning of the water injection mechanisms, and by inappropriate injection. In contrast to the injector positioning for an evaporation cooler, water injection in a cement grinding mill does not require homogeneous distribution of very small, even sized droplets throughout the entire section. This makes possible the use of comparatively lower water pressures and simple nozzles. One must insure, though, that no unevaporated water droplets reach the louvered slides, while they can fall harmlessly onto the ball bed. The rate of water evaporation on the grinding body is sufficiently high to preclude onset of the deposition process.

Figure 7. Clogged louvered slide in a cement grinding mill.

Water evaporation is fastest in the fine chamber of the mill, since it is the place of highest temperatures. It is recommendable, however, to provide water injection also in the first chamber, so that the water amounts required for unobjectionable operation of the electrostatic filter are available in every case. Experience has shown that grinding facilities exist in which the required amounts of water can not be injected only in the fine chamber. Should it be necessary to inject additional amounts of water on the feed material side, the recommended procedure is to inject a constant amount of water into the fine chamber, and use injection into the first chamber only when changes in the operating conditions (such as input of more highly tempered clinker) make it necessary. It is obviously also possible to vary the water amounts in both chambers.

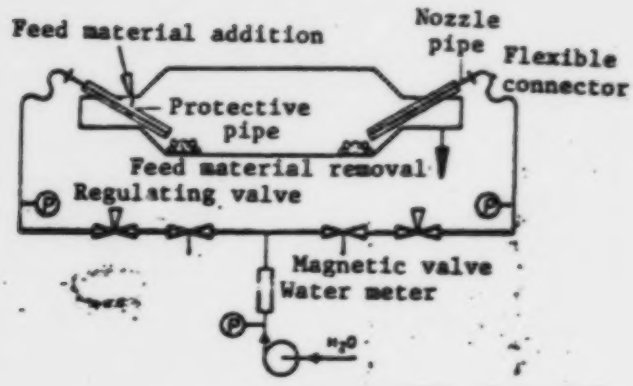

Figure 8. Water injection in cement grinding mills.

Figure 8 shows a typical arrangement of the injection mechanism. Water is fed to the nozzle through a pump, or directly from the net at a pressure of at least 5 atm via a water meter, a magnetic valve and a regulating valve. The nozzle pipe itself is placed inside a covering pipe, providing some space for scavenging air to prevent deposit formation in the nozzle.

To prevent water bleeding into the mill, the magnetic valve must be connected to and governed by, the mill feeding mechanism. In this way, if the flow of feed material is interrupted, the water supply is automatically shut off. At the same time, the regulating valves have to be set at minimum position, so that the injection of too much water or no water at all can be avoided during start-up. The installation of the water injection mechanism will be different in the first and the fine chambers. On the feed side, injection should occur in the direction of flow, towards the center wall. Since the water droplets must be prevented from reaching that wall, a gross nozzle aimed at the ball bed is recommended.

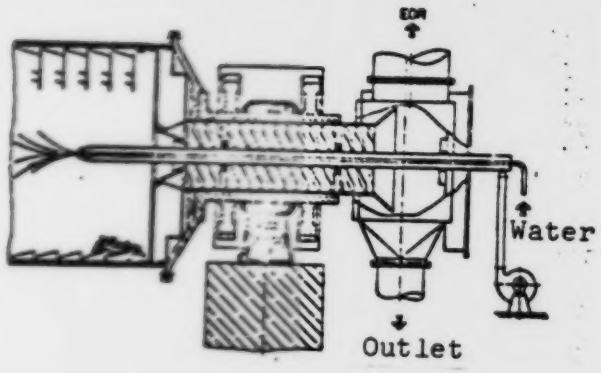

Figure 9. Construction details of a mill injection mechanism.

In the fine chamber, counter-current injection is preferred. The center wall is endangered only if it is sprayed directly, which can occur only when the nozzle pipe projects too far into the mill, or when the injection pressure is too high. It is much more important, however, to prevent clogging of the removal wall, something that could occur if the nozzle does not project far enough into the mill, or if the water pressure is too low, so that unevaporated water droplets are carried by the air stream.

The water pipe enters through the mill outlet magazine and is connected to the rotating part of the mill by sealed ball bearings. The length of nozzle pipe projecting into the mill interior depends on the water pressure selected, and must be carefully determined.

It must, of course, be possible to vary the water amounts to be injected, depending on the temperature and the humidity of the feed material, the particle size of the cement and the mill capacity. In principle, this can probably be done manually, in which case the

current consumption by the electrostatic precipitator - as shown in Figure 5 - is a good indication of the condition of the gas in the mill. It would be difficult, in this case, to operate under optimal conditions, especially under varying feed conditions. While excessively low amounts of water can deteriorate the dust content in the purified gas, an excess can adversely affect the stability of the cement. This is particularly critical in the case of grinding of highest grade cements, since in this case the smaller dust particle size requires larger amounts of water to maintain stable operating conditions for the electrostatic precipitator.

Hence, automatic regulation of the water supply is desirable in all cases. The indicator could be the moisture content of the spent air. For instance, the water dew point can be measured with a lithium chloride detector which indicates the dew point corresponding to the limiting temperature between moisture and dryness. One must ensure, though, that the detector operates in absolutely pure gas, which can be achieved in a bypass in which the gas is purified by means of a filter cartridge.

In the case of facilities that operate at constant spent gas temperatures because of stable feed conditions, it will be sufficient to regulate on the basis of a constant dew point.

In the case of large variations in operating conditions, the dew point is not, by itself, sufficient to ensure even and satisfactory precipitator operation. In this case, the regulation must take the gas temperature into account. The range of regulation is then the difference between spent gas temperature and water dew point. As is known from the operation of coarse grinding mill electrostatic precipitators, this difference must be smaller at low temperatures than at higher temperatures. This fact must also be taken into account when the regulating mechanism is installed.

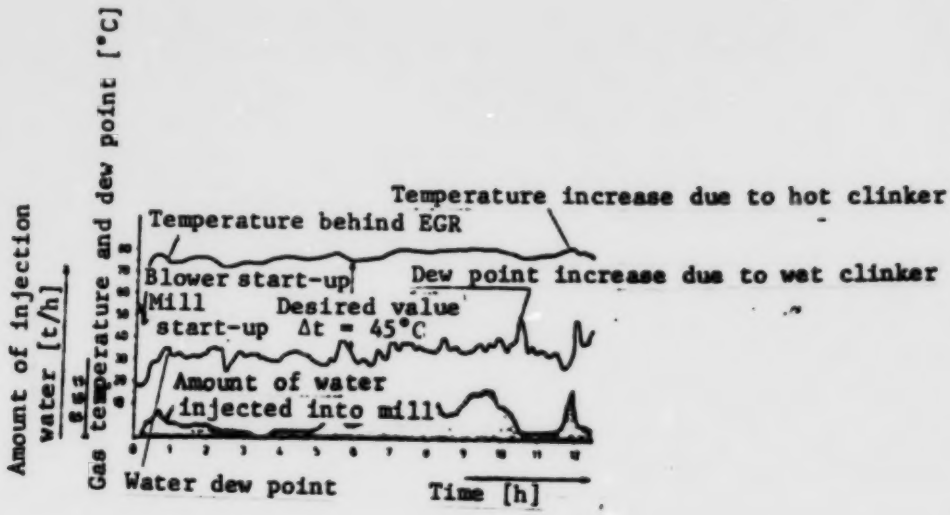
Amount of injection water [t/h]
Gas temperature and dew point [°C]
Temperature increase due to hot clinker
Temperature behind EGR
Blower start-up
Dew point increase due to wet clinker
Mill start-up
Desired value Δt = 45°C
Amount of water injected into mill
Water dew point
Time [h]

Figure 10. Section of strip-chart record. Temperature and humidity variations in the feed material.

Figure 10 reproduces the temperature and humidity variations in the feed material as obtained from a strip-chart recorder. It can be appreciated that the amount of water to be injected must be constantly changed, in order to maintain the desired value of the temperature dew point difference.

5. Measurement results from operating facilities

Table 2 compiles the values for electrostatic precipitators used in several cement grinding mills. None of the facilities used cyclones ahead of the precipitators. In all of them, crude gas dust content before the electrostatic precipitator was up to 800 g/Bm^3. The measurement results are limited to facilities in which Portland and blast furnace cements of normal and medium quality are produced. However, with an appropriate dimensioning of the electrostatic precipitator, dust removal by this unit is not a problem in the grinding of highest grade cements either.

The table gives a summary of the specific amounts of air for various grinding mill performance levels, the introduced amounts of water and also shows the filter behavior as a function of temperature and dew point.

It also shows the influence of the dust resistance clearly. The dust resistance depends on the raw material and the exhaust gas of the ovens for each facility.

For example, in plant III (line 6) the introduced amount of water is 1%, the temperature is 95° C and the water dew point is 30° C, which leads to a purified gas dust content of 50 mg/m^3. In plant II (line 4) twice the amount of water is required per unit of mill capacity in order to obtain the same purified gas dust content. However, in this case higher quality cements are ground. This can certainly be traced through the increase in dust resistance which occurs as the dust fineness is increased.

The measurements furthermore show that the average specific air amount of 0.55 m^3/kg cement lies within the range of 0.2 to 1.8 m^3/kg cement. We can not univoquely state, however, whether the air amounts measured at the facilities mentioned refer always only to the mill's spent air, or whether, in addition, the spent air of the different conveying mechanisms is included.

The average specific water amount, referred to mill capacity, is 2.35%, in a range that varies between 1 and 4.16%. The installation of plant VI (next to last line), for instance, shows that it is possible to inject an amount of water equivalent to 2.25% of mill capacity, for an unusually low specific spent gas amount of 0.2 m^3/kg cement, if one is willing to operate the mill at correspondingly higher temperatures. As can be observed from the purified gas values, the spent gas conditions are still favorable, since these higher temperatures also

TABLE 2. RESULTS OF DUST MEASUREMENTS AT ELECTROSTATIC PRECIPITATORS INSTALLED AT THE OUTPUT OF CEMENT GRINDING MILLS.

Plant/Mill	Mill capacity, t/h	Kind of cement	Amount of spent gas, m^3/h	Specific spent gas amounts, m^3/kg cement	Injected water amounts, m^3/h	Specific water amounts, % of mill capacity	Temperature, °C	Dew point, °C	Crude gas dust content, g/m^3	Purified gas dust content, g/m^3

correspond to higher due points. The second measurement taken at the plant indicated (last line) shows, however, that at excessively low moisture contents the purified gas dust content increases.

We can see from the measurement results that for unobjectionable operation of the electrostatic precipitator it is necessary to so calculate the water injected into the cement grinding mill that the amount of water corresponds to approximately 3% of mill capacity. Amounts of water are varied because of varying operating conditions. The amount of water actually necessary is predicated from the temperature and the humidity of the feed material and the particle size, as well as atmospheric conditions (moisture content of external air). Table 2 shows that in all cases but one - in which the specific spent air amount is also extremely high - this percentage is sufficient, and that it represents the maximum. Beyond that, practice has shown that it is possible to operate cement grinding mills with this amount of water.

Several parties have repeatedly stated that one of the disadvantages of the electrostatic precipitator is that its dust removal capacity is reduced during start-up and shut-down of the mill, while the bag filter provides uniformly satisfactory purified gas values even under these conditions. This is probably true if the special physical circumstances during these two operating periods are not taken into account so far as the electrostatic precipitator is concerned.

During cold starts (i.e., start-ups following prolonged shut-downs of the mill) the operating temperatures of the electrostatic precipitator rise to up to 60°C - as can be seen from dust resistance curves. The precipitator operates unobjectionably even without water injection. At that point, water injection must be switched on, either manually or automatically.

If a still warm mill is restarted after a brief shut-down, then the water must be injected immediately after addition of the feed material.

During shut-down of the mill, the spent gas blower installed behind the electrostatic precipitator should be turned off together with the interruption in feed material addition and pipe mill operation.

If the mill has to be operated without loading, the opening of doors or baffles in the spent gas circuit is recommended, so that the spent air fed to the electrostatic precipitator is cool enough, for the reasons mentioned above.

If these precautionary measures are taken into consideration, the start-up and shut-down of the cement grinding mill need not be an unsurmountable problem for the electrostatic precipitator.

6. Comparison between the electrostatic precipitator and fiber filters.

We had already indicated that fibrous material filters are the only alternative to electrostatic precipitators for the dust removal from cement grinding mills. Due to the efficacy of the fibrous material, no water injection is needed with these filters. However, high clinker temperatures may still require water injection to prevent excessively high temperatures in the finished cement. Due to the increase in the moisture content of the spent air, this can lead to caking in the filter fibers, unless additional expenses are incurred to provide increased heat insulation and heating of the scavenging air.

The spent air amounts of the mill are, of course, higher if only air is used for cooling; the increase is approximately 0.5 to 0.7 m^3/kg cement for the mill itself. To this must be added the spent air of the conveyor mechanisms which is, however, often purified in a

separate filter. If fibrous filters are used, one must expect specific spent air amounts - including the conveyor mechanisms - of 0.8 to 1 m^3/kg cement. If electrostatic precipitators are used, these amounts can be easily reduced to 0.4 m^3/kg cement, depending on the amount of water injected. In special cases, values as low as 0.2 m^3/kg cement are satisfactory. The required water amounts are, at the most, 2 to 3% of the clinker capacity. Due to the comparatively lower air requirements, the electrostatic precipitator does not require significantly larger space than a fiber filter. To this we must add that the electrostatic precipitator can be installed outside without problems. If the two procedures involved are to be compared, one must take into consideration that normally, centrifugal separators must precede the fiber filters to reduce the dust load in the filter and thus keep within limits the wear and tear of the fibers. While the size of the electrostatic precipitators can be positively affected by an improvement of the spent gas conditions, the size of fiber filters can be only minimally affected by varying the filter load or the filter medium. As is well known, excessive specific loading has a deleterious effect on the useful life of the medium, which can result in an expensive increase in downtime.

We will not attempt to perform a fast and easy comparison of the economics involved in both operations, since in this context it is very difficult to make generally valid comparisons. The question as to the total economic feasibility of either procedure must be answered for each particular case, after giving full consideration to local conditions.